PRIFYSGOL BANGOR / BANGOR UNIVERSITY

PRIFYSGOL
BANGOR
UNIVERSITY

Diversity of fishing métier use can affect incomes and costs in small-scale fisheries

Cambie, Giulia; Pantin, Julia; Lincoln, Harriet; Hiddink, Jan; Lambert, Gwladys; Kaiser, Michel

Canadian Journal of Fisheries and Aquatic Sciences

DOI:
10.1139/cjfas-2016-0367

Published: 01/01/2017

Peer reviewed version

Cyswllt i'r cyhoeddiad / Link to publication

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):
Cambie, G., Pantin, J., Lincoln, H., Hiddink, J., Lambert, G., & Kaiser, M. (2017). Diversity of fishing métier use can affect incomes and costs in small-scale fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, *74*(12), 2144-2152. https://doi.org/10.1139/cjfas-2016-0367

Hawliau Cyffredinol / General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

05. May. 2023

Diversity of fishing *métier* use can affect incomes and costs in small-scale fisheries

Giulia Cambiè[1,2], Julia R. Pantin[1], Harriet Lincoln[1], Jan G. Hiddink[1], Gwladys Lambert[1], Michel J. Kaiser[1]

[1] School of Ocean Sciences, Bangor University, Askew Street, Menai Bridge, LL59 5AB, UK

[2] Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, NR33 OHT, UK

Corresponding author: Giulia Cambiè

Email: giulia.cambie@gmail.com

Abstract

The implementation of an ecosystem based approach to fisheries management (EBFM) in multispecies fleets has the potential to increase fleet diversification strategies, which can reduce pressure on overexploited stocks. However, diversification may reduce the economic performance of individual vessels and lead to unforeseen outcomes. We studied the economic performance of different fleet segments and their fishing *métiers* in Wales (UK) to understand how the number of the *métiers* employed affects fishing income, operating costs and profit. For the small-scale segment more specialized fishers are more profitable and the diversity of *métiers* is limiting both the maximum expected income and profit but also on the operating costs. This last result may explain the propensity of fishers to increase the number of *métiers* for at least part of the studied fleet. Therefore, while for some vessels increasing the diversity of fishing *métiers* may be perceived to limit economic risk associated with the interannual variability of catches and prices and/or to reduce their operating costs, it can ultimately result in a less profitable activity than more specialised vessels.

Key words. Fishing *métiers*, Fishers' behaviour, Economic performance, Linear quantile mixed model, Small-scale fishery

Introduction

In recent decades there has been increasing interest in understanding the role of fishers' behaviour in the exploitation of marine resources (Branch et al. 2006). Hilborn (1985) suggested that most fisheries problems, including the collapse of many fisheries, can be attributed to a lack of insight into fishers' behaviour, rather than a lack of biological knowledge about fishery resources. An important aspect of fishers' behaviour is their choice of fishing *métiers*. A *métier* is defined as a group of fishing operations that target a specific assemblage of commercially important species, using a specific gear, during a period of the year and within a specific geographic area (e.g. Pelletier and Ferraris 2000; Deporte et al. 2012). Understanding the fishing *métiers* used by multispecies fleets and the behavioural drivers underpinning their choice is crucial to be able to model fishers' responses to regulations (Salas and Gaertner 2004; Fulton et al. 2011).

A growing literature has focused on defining the main drivers of fishers' behaviour and their associated fishing strategies, defined as a sequence of decisions, which includes *métier* choice over various time scales (van Putten et al. 2011). The current consensus is that fishing strategies are driven primarily by the economics of the fisheries (e.g. Robinson and Pascoe 1997; Marchal et al. 2009; Andersen et al. 2012). The most common approach to studying fisher decision-making is based on the profit-maximisation concept, which assumes that fishers select *métiers* to optimise net revenues with minimal cost (Gordon 1954; Hilborn and Kennedy 1992). This assumption underlies many bio-economic models that are used to assess possible management scenarios (e.g. Prellezo et al. 2012). However, it is also recognised that fishers' behaviour may be based on a number of other drivers, including attitudes towards risk and their preferred risk-coping mechanisms, which may vary among individuals (Robinson and Pascoe 1997; Herrero and Pascoe 2003; Holland 2008; van Putten et al. 2011).

Fishers face high financial risk due to the interannual variation in their incomes. This is a problem common to many businesses that are dependent on natural resources, and fishers, like farmers, can implement a variety of approaches to hedge their revenues and reduce variability about the expected performance (Sethi 2010). In agriculture for example crop diversification is a common strategy to minimise risk and stabilize harvest in the face of unpredictable weather (Miller et al. 2002). Similarly, fishers can diversify their activity across a variety of fisheries and therefore a variety of *métiers*. However, not all fishers decide to diversify their activity, and two different behaviour patterns have been defined; "specialists" who typically operate in one fishery (thus using one or few *métiers*) and "generalists" who participate in many fisheries (many *métiers*) (Smith and McKelvey 1986). Therefore, while increasing the diversity of the *métiers* used and consequently the range of exploitable stocks can reduce the risks associated with natural and economic variability, not all fishers adopt this strategy. Kasperski and Holland (2013) analysed for the first time the relationship between income diversification (incomes that derive from a variety of fisheries) and its variability at the level of individual vessels on the US West Coast and in Alaska and demonstrated that diversification of fishing activity is correlated with a reduction in the interannual variation of revenue. While this finding is a positive aspect of the diversification of the fishing practice, it does not indicate whether increasing diversification is associated with a change in fishing efficiency such that specialists may differ in their efficiency from generalists. The determinants of the latter are no-doubt context-specific. The potential change in fishing efficiency associated with the diversification of the *métiers* employed is a topic noted in the literature (Smith and McKelvery 1986) but so far not documented or quantified empirically.

In this paper we investigate how the number of *métiers* used affects fishing income and profit in an inshore fishery in Wales (UK). This study examines if the profit-maximisation concept drives switching-behaviour between multiple *métiers* and thus if the increase of the diversity of the *métiers* employed is associated with an increase in yield and profit. To this end, we first analysed the economic performance of the main coastal fleets operating in Welsh waters and we identified the fishing *métiers* used. We then focused our attention on the small-scale segment, which was the part of the fleet that was the most representative in terms of number of vessels in the study area. In northern Europe most studies on fishing *métiers* have focused on medium- and large-scale fisheries (vessels $\geq$ 10 m length) (e.g. Ulrich and Andersen 2004; Andersen et al. 2012; Davie et al. 2015), because these sectors are data rich (official log books are compulsory only for vessels $\geq$ 10 m length). The focus on larger vessels in northern Europe has meant that small-scale fleets have been somewhat neglected to date (Guyader et al. 2013). Our study thus contributes not only to quantify empirically the relationship between diversification of *métiers* and the economic performance for small-scale vessels, but provides new insights into the fishing practices for this part of the fleet.

Methods

Data source and fleet segmentation

Data on technical characteristics, landings and economic performance of 42 fishing vessels were obtained from interviews with vessel owners between July and December 2013. Data were collected on the crew (number of fishers and the sharing system under which the fishing income was divided among members of the crew and the boat owner), fishing effort (total number of fishing days by gear and month), costs and production. The costs data focused on operating costs (fuel, lubricating oil, bait, ice, food), fixed costs (including harbour dues, insurance, maintenance costs and the annual interest payment) and investments. The production data included the total monthly catch and monthly catch by species (in weight, kg) and the average landing price by species and month (£/kg. Exchange rate at 01 January 2012: 1GBP=1.554 USD, source: www.oanda.com). The information requested during the interviews was related to the fishing activity along the Welsh coast in 2012. This information was used to perform an initial analysis of the economic performance of the fleet and informed the subsequent estimation of the fishing *métiers* used and their relationship with income, operating costs and profit.

Fishers were randomly selected from the main fishing ports located around the Welsh coast (Figure 1) and, where possible, were contacted before the interview through fishing associations. The interviews were focused on three main fleet segments that were identified from the UK fleet economic performance dataset (e.g. Lawrence and Anderson 2014) and from suggestions obtained from the main fishing associations. These segments were:

- vessels ≥ 10 m length combining mobile (mainly scallop dredge) and passive (pots) gears (we refer to this segment as "scallop-dredge medium-scale (MS)");
- vessels ≥ 10 m length using passive gears only (pots and nets) ("pots-and-nets medium-scale (MS)");
- vessels < 10 m length using passive gears only (mainly pots and nets) ("pots-and-nets small-scale (SS)").

According to the EU Fleet Register for the UK (DG MARE 2015), a total of 365 fishing vessels belonging to those three segments were registered in Wales. For each segment we calculated the minimum number of interviews required to obtain sufficient economic information that was representative of the segment. To this end, the heterogeneity of fishing incomes within a fleet segment needed to be estimated. The coefficient of variation *CV* of a proxy for the fishing incomes (CV_i) was estimated across all vessels. This proxy was obtained by multiplying the vessel length by the number of fishing months for each vessel of the whole population. These data were obtained from the official census of Welsh vessels registered in 2012 (DG MARE, 2015). Then an extension of the Neyman optimal allocation (Cochran 1977; Van Iseghem et al. 2011) was applied to the official census. The minimum sample size n_i required to be representative for segment *i* was computed as (1):

$$n_i = N_i \frac{1}{1+N_i L^2/(4CV_i^2)} \tag{1}$$

Where N_i is the segment size (total number of vessels), CV_i is the coefficient of variation of proxy fishing incomes, and L is the minimum required precision (L = 0.25) to be achieved for the fleet estimate of the parameter of interest under the regulation of the Data Collection Framework (DCF) of the European Union (https://datacollection.jrc.ec.europa.eu/wordef). We achieved the required minimum sample size for each of the three main segments: scallop-dredge medium-scale (MS) (n=6, 86% of the segment; required n=6), pots-and-nets medium-scale (MS) (n=5, 28% of the segment; required n=5) and pots-and-nets small-scale (SS) (n=31, 9% of the segment; required n=6).

Data analysis

Statistical analyses were carried out using R version 3.0.2 (R Core Team 2013) and involved three steps.

Step 1: Analysis of the economic performance

Data were first analysed to provide a general overview of the economic performance of an average fishing vessel for each of the three main segments. Cost indicators included fixed costs (administrative costs, maintenance costs and depreciation), operating costs, opportunity cost of capital (benefits that the vessels' owners could have obtained by investing their capital in an alternative risk-free investment, e.g. national debt. We considered 0.32% as interest rate for UK 1-Year Bond in 2012) and average wage. Profit indicators comprised Vessel Physical Productivity (VPP) (tonnes of landings), Capacity Physical Productivity (CPP) (tonnes of landings per gross tonnage) and Vessel Productivity (VP) (total incomes, calculated as first sale value of landings). Finally, the profitability indicators included the total capital invested, the net profit (the difference between the total income and all costs) and the Rate of Return on Investment (ROI) (percent ratio of yearly net profits plus the opportunity cost in relation to the investment). This analysis represented an essential preliminary step to understand differences in the magnitude of the economic performance between fleet segments, before the economic indicators were considered at the *métier* level. Details of the calculations are given in Table 1 in Cambiè et al. (2012).

Step 2: Identification of the fishing métiers

To identify the fishing *métiers* used by the studied fleet, we aggregated the catch of each species by boat on a monthly basis, according to Pelletier and Ferraris (2000). For each fishing gear used by the main segments, a matrix of catches (kg) was constructed with rows denoting monthly fishing operation per boat and columns denoting species. Only month per boat combinations with non-zero catches were included. The data matrix was then transformed to the percentage species composition of each month per boat combination, to produce the monthly catch profile. A similarity matrix based on the minimum variance criterion of Ward (1963) and chord distance (Legendre and Legendre 1998) was used to run an agglomerative hierarchical clustering, where the clusters represent the *métiers*. The silhouette coefficient, which represents a measure for the quality of the clustering and provides a good aid in choosing reasonable cut-off points in the cluster (Rousseeuw 1987), was calculated to determine the correct number of clusters for each fishing gear.

A multiple correspondence analysis (MCA) was then used to analyse the pattern in the relationship between the *métiers*, month and fishing area and thus to test the potential seasonal and spatial differences in fishing strategies. In particular, the MCA was applied to the data matrix built with the 607 monthly fishing operations recorded in the interviews as individuals and the three categorical variables: fishing area (north, mid and south Wales), *métiers* and month. The separation between north, mid and south Wales (Figure 1) was based on evidence of i) different demographic characteristics and the distribution of some target species over a latitudinal gradient (e.g. Haig et al. 2015; Cambiè et al. 2016), which could affect the adopted fishing strategy, and ii) differences in the distribution of fishing effort and the gears used (Pantin et al., 2015). To calculate the percentage of the data variation (inertia) explained by the MCA, adjustment to inertias in the Burt matrix analysis was applied (Greenacre 2006; Greenacre et al. 2010). The R package "ade4" was used to perform the analysis (Dray and Dufour 2007).

Step 3: Analysis of the effect of the métiers diversity on income, operating costs and profit

The average daily income by month was estimated, from the catch profile and the corresponding first sale value, for each of the most common *métiers* used by the studied fleet (we defined "most common" as the *métiers* used by at least five fishers). This information was required to explore the economic performance at the *métier* level and to assess which *métier* was associated with the highest incomes. Afterwards, we investigated the relationship between the number of *métiers* used by the individual vessels in a month and the average daily income, operating costs and profit. These three economic indicators were calculated on a daily basis to remove the effect of the number of fishing days in a month (which were highly dependent on weather conditions) on the economic performance of the activity. To this end, for each month and vessel the fishing incomes and operating costs were divided by the corresponding number of fishing days. The daily operating profit was then calculated by subtracting the daily operating costs from the daily income. The analysis was carried out on the "pots-and-nets small-scale" segment only (n=31 fishers for a total of 308 monthly fishing operations recorded), being the part of the fleet that was most representative in terms of number of vessels in the study area and because the low number of observations associated with the medium-scale segments (scallop-dredge medium-scale, n=6 fishers and pots-and-nets medium-scale, n=5 fishers).

An initial exploration of the distribution of the data showed that the income and costs were limited by the number of *métiers*, i.e. a lower number of *métiers* could result in a higher income but could also result in a low income, while a high number of *métiers* always resulted in a low income. A Linear Quantile Mixed Model (LQMM) (Geraci and Bottai 2014) was used as this is a method suitable for data with unequal variances and unlike other non-parametric regression models it allows for the examination of limiting factors (Koenker and Bassett 1978). This analysis was preferred to the ordinary least squares regression methods because the latter method would fail to capture a relationship between the number of the *métiers* used on a monthly basis and the average daily incomes and daily operating costs, due to the presence of unmeasured factors that contribute to the variability of the incomes and costs (e.g. fisher's experience, free-risk attitude, variation in the local market price, etc.). In a quantile regression, the response variables (daily incomes, daily operating costs and daily operating profit) can be constrained by many potential unmeasured factors, but cannot change by more than some upper limit set by the measured factor (which was assumed to be the number of *métiers* in this study) (e.g. Kaiser et al. 1994; Cade et al. 1999; Cade and Noon 2003). Therefore, the quantile regression should reveal the potential limiting effect of the number of the *métiers* used on a monthly basis on the distribution of the average daily incomes, daily operating costs and ultimately daily operating profits.

The relationship among dependent and independent variables was studied at three different quantiles (tau = 0.10, 0.50, 0.90) by using a linear model for quantile regression that allowed for the correlation between observations that belong to the same unit or cluster (fisher). LQMM represents a novel method that includes a subject-specific (fisher) random intercept and random slope, thus accounting for within-group correlation (Geraci and Bottai 2014). According to Geraci (2014) the independent variable (number of *métiers* by month) was mean-centered, to remove the correlation between the random intercept and the slope thus facilitating the interpretation of the results. The R package "lqmm" was used to fit linear quantile mixed models based on the asymmetric Laplace distribution (Geraci 2014).

Results

The three fleet segments (scallop-dredge medium-scale, pots-and-nets medium-scale and pots-and-nets small-scale) had different technical characteristics and economic structure. The fishing capacity in terms of engine power, gross tonnage, number of crew and length of vessels differed considerably between the small-scale segment and the two medium-scale segments (Table 1). The operating costs (OC) were directly related to the number of fishing days (Table 2). While fuel was the most expensive item for the scallop-dredge MS (77% of the OC), the bait was the most important operating cost for the pot-and-nets MS and SS (38% and 45% respectively). In terms of depreciation, fishing gears were the most common and expensive investment for the medium scale segments (61% and 53% for scallop-dredge MS and pot-and-nets MS respectively), while engines, winches and other parts of the vessel represented the most expensive type of investment for the small-scale segment (66%). Vessel productivity in terms of weight and value of landings was an order of magnitude higher in the medium-scale segments than in the small-scale segment (Table 2). Scallop-dredge MS appeared to be the most proficient segment in terms of net profit while pots-and-nets MS segment was most proficient in terms of Rate of Return on Investment. This difference was mainly due to the higher amount of investments that scallop-dredge MS made, which resulted in a reduction of the related ROI.

The fleet segments analysed were composed of multi-species fisheries that operated with a large diversity of fishing gears, including both passive and active gears. The passive gears used were pots targeting lobster, crabs, prawn and whelk, single wall nets (gill nets and tangle nets), trammel nets (three walled nets), rod and line and longlines. The active gears were restricted to scallop dredges and otter trawls. While the passive gears were used by all three fleet segments, the active gears were only used by the scallop-dredge medium-scale segment.

The cluster analysis of the catch profile showed that out of the 11 fishing gears used by the studied fleet, four fishing gears (lobster pot, gill net, rod and line and tangle nets) were separated into different *métiers* (Figure 2). The cut-off points for each gear ranged from 15 to 20% dissimilarity as determined from the silhouette coefficient: 0.46 for lobster pot, 0.63 for gill net, 0.96 for tangle nets and 0.67 for rod and line. For these gears, the catch profile of each fishing *métier* was characterised by a main target species (> 50% of the catch in weight) and one or more secondary species (Table 3). The remaining gears (n=7) were not separated into multiple *métiers* by the cluster analysis as they were not characterised by multiple catch profiles and most of them (n=5) were defined by a single-species catch. Lobster pot appeared to be the gear characterised by the highest diversity in terms of catch profile as it was separated into 3 *métiers*. It was also the gear most widely used by the studied fleet, representing the main gear for 74% and 60% of the "pots and nets" small-scale and medium-scale segments respectively. The small-scale segment used on average 1.5 *métiers* per vessel per month, pots-and-nets medium-scale vessels used 1.4 *métiers* per vessel per month and scallop-dredge medium-scale used 1.1 *métiers* per vessel per month.

The relationship between fishing *métiers*, fishing location and month was assessed with a multiple correspondence analysis (MCA). The explained cumulative inertia in the first two dimensions was 51%. Therefore, 51% of the variation in fishing operations was explained by the relationship between *métiers*, season and location (Figure 3). The MCA showed that the different fishing *métiers* were related to the seasonality of the target species and the capture location. For example, spider crab represented the main target species for three different *métiers* (FPOl_2, TaN_1 and FPOsp_1). Although all three *métiers* were used mainly in the summer (when spider crabs are more abundant), they were employed in different locations: lobster pot in south Wales and tangle net and spider pot in mid Wales. The prawn fishery (FPOp_1) also showed strong seasonality (almost absent in summer, with an increase of use in spring, autumn and winter) and a strong relationship with the fishing location, as it was concentrated in mid Wales. The use of tangle nets that targeted crayfish (TaN_2) was typical of south Wales during winter, while the scallop fishery (DRBk) was mainly concentrated in north and mid Wales.

For the small-scale segment, the whelk pot (FPOw_1) was the *métier* associated with the highest daily income across the entire year, followed by pots that targeted spider crab (FPOl_2) and pots targeting brown crab (FPOl_3), while for medium-scale segments, scallop dredges and whelk pots were the main and most proficient *métiers* (Figure 4).

The relationship between the average daily income, operating costs and profit and number of *métiers* used on a monthly basis was assessed through the LQMM, which was performed only for the pots-and-nets small-scale segment (small vessels using only passive gears) as this was the most representative segment in terms of number of vessels and was also the segment with the minimum number of data required to run this analysis. The magnitude of the decline (slope) of daily incomes and daily operating costs for the increase of the number of the *métiers* used on a monthly basis increased with the quantile level (0.1, 0.5 and 0.9) (Figure 5). However, at the 10th and 50th quantiles this decline was not significant as the confidence interval of the slope included 0. Thus an average vessel at lower quantiles (0.1, 0.5) seems to have a similar economic performance independently on the number of the *métiers* used. In contrast at 90th quantile the relation became significant, which demonstrated that the number of the *métiers* used acts as a limiting factor of daily income and daily operating costs with rates of change increasing at the quantiles near the maximum response. At the 90th quantile the relationship shows that for each additional *métier* used, daily incomes and daily operating costs decrease by £256 and £46 respectively (Figure 5, p=0.007 and p=0.027). Consequently, the daily operating profit also significantly decreased at the 90th quantile by £203 for each additional *métier* used (p=0.009). This significant quantile regression indicates that other factors beside the number of *métiers* can also negatively affects income and costs but, for a vessel at higher quantile (0.9) (vessels with a very good economic performance), a higher number of *métiers* always results in a lower income and, ultimately, in a lower profit.

Discussion

Our study provided a comprehensive analysis of the fishing strategies employed by the small-scale and medium-scale segments of the Welsh fleet. Three main segments were identified as representative of the Welsh fleet from a socioeconomic perspective (number of vessels, fishing effort and income produced), one small-scale (pots-and-nets small-scale) and two medium-scale (scallop-dredge medium-scale and pots-and-nets medium-scale). All three segments were profitable. There was a moderate rate of return on investment (ROI) (which depends on the rate profit/capital invested) for the scallop-dredge and the small-scale segments and a high ROI for the pots-and-nets medium-scale segment. The ROI for the small-scale segment and scallop dredge medium-scale was similar (around 7% per vessel). However, this similarity was not an expression of a similar economic structure, which appeared to be extremely different between the two segments. For the small-scale segment, the moderate ROI was the result of a moderate profit, while for scallop-dredge medium-scale it was the result of the large amount of capital invested by the segment. Regular monitoring of the economic performance of the scallop-dredge medium-scale segment is therefore needed to understand if the large investments in harvesting capacity yield progressively lower returns to fishers. In this case, scallop-dredge medium-scale could be close to a situation of overcapitalisation (and possibly overcapacity), increasing risk of overexploiting the target stock. The latter has clear policy implication and may require government intervention to reduce fishing capacity in the fleet. Conversely, the pots-and-nets medium-scale segment appeared highly profitable with a ROI of about 20%. This value indicates that the economic performance of this fleet segment was good during 2012, since a ROI of >10% is considered a good result (Tietze et al. 2005). Profitability indicators are particularly useful for assessing capacity levels of fisheries (Ward et al. 2004) and a good economic performance can encourage investment in fishing. It is therefore likely that the pots-and-nets medium-scale segment will invest at least part of the benefits in vessel technology, for example, by upgrading their engines, electronic equipment or fishing gears (e.g. number of pots).

Our results identify the multi-*métier* nature of Welsh fisheries. A total of 16 *métiers* were identified and differences in fishing *métier* use were detected between the three fleet segments. While scallop-dredge medium-scale appeared to be a segment more specialised in using one single *métier*, the rest of the segments and in particular the small-scale segment, were characterised by use of a higher diversity of *métiers* and reflected a more dynamic nature of their fishing operations. The higher specialisation of the medium-scale segments might have been driven by the same investments that improved technical efficiency over time, which are likely to facilitate the consolidation of a specific fishing strategy, thereby driving decreases in diversification (Kasperski and Holland 2013; Squires and Vestegaard 2013).

Our results show that the availability of the target species, the fishing location and the season appeared to be important drivers of the choice of fishing *métiers*, in accordance with multiple studies on this subject (e.g. Ulrich and Andersen 2004; Holland 2008; Andersen et al. 2012). This study thus confirmed the need to consider the different spatial and temporal scales when applying management measures, as the response to regulations might vary depending on the geographical and seasonal context in which they are applied. For this reason decisions affecting fishers' communities and local stocks may not be effective if implemented on a large scale when local conditions differ. The variety of the fishing *métiers* used and the differences in their catch composition, temporal and spatial distribution, suggest the possibility of improving the resource management by changing the current focus of management from a gear-specific approach to a *métier*-level focus, especially for small-scale fisheries. For example, given the current gear-level management approach, an increase in the number of vessels using lobster pots would be mainly related to an increase in the fishing mortality of the European lobster, whereas in reality the proportion of the species caught depends on where and when this hypothetical effort increase would take place.

The main finding of this study was the negative relationship between the diversity of the *métiers* employed and the economic performance of the fishing activity for the most efficient small-scale fishers. We found that, for these fishers, the number of *métiers* used limited their maximum expected income and, ultimately, their maximum expected profit, with fishers with the highest incomes using a restricted number of *métiers*. As this analysis was focused on the small-scale segment, which use only passive gears, this finding cannot be considered representative of the whole fishing fleet. However, it provides us with important insights into the potential trade-off between risk reduction through diversification and efficiency loss for this fleet segment. Small-scale vessels are generally characterised by lower technological creep than industrial vessels and they cannot rely on sophisticated equipment and engine power to maximise their capture rates. Thus, the knowledge of the behaviour, seasonality, and distribution of target species is a key factor in determining the success of their fishing activity (Andersen et al. 2012). This set of expertise, also known as Local Ecological Knowledge (LEK), is built through experience accumulated over years (e.g. Davis and Wagner 2003) and often focuses on a restricted number of species (e.g. Neis et al. 1999) or on a main type of fishery (Ulrich and Andersen 2004). It therefore seems plausible that fishers only have an in-depth knowledge of the ecology and the distribution of relatively few species. Therefore, adoption of strategies that restrict the number of *métiers* used could lead to maximisation of catches and income across a year by focusing investment on high value species (e.g. whelk, lobster) for which fishers have substantive LEK. This strategy is typical of specialist fishers, which operate more efficiently in the fishery of their speciality (Smith and McKelvey 1986). In contrast, a fishing strategy characterised by the use of multiple *métiers* targeting many different species may be considered typical of generalist fishers with a lower level of specialisation and a less in-depth knowledge of the target species, which could ultimately lead to a lower level of catch and incomes. Smith and McKelvey (1986) described generalists as fishers that try to hedge their income by mixing different fishing practices (and thus different *métiers*). While this strategy may be effective in reducing the interannual income variability (Kasperski and Holland 2013), it does not maximize profit.

Our results also show the limiting effect of the number of *métiers* used on the operating costs, which could explain the propensity of increasing the number of *métiers* for at least part of the studied fleet. The reduction of the operating costs associated with the fishing activity could therefore be considered a driver behind the use of multiple *métiers*, especially when the *métiers* with high costs of bait and fuel, such as lobster and whelk pots, are alternated with low-cost gears such as gill nets, trammel nets and tangle nets. Moreover in UK the increase of the number of gears used is not associated with an increase of the costs of the fishing licence and the species exploited by the studied fleet are all non-quota species. Therefore, the increase of the number of the harvestable stocks does not require the purchase of fishing quota or any other fixed cost besides the price of new potential gears. The reduction in operating costs as a driver for using multiple *métiers* is consistent with the characteristic of a generalist fisher, as described by Smith and McKelvey (1986). According to these authors, the economic decisions of a generalist fisher focus on keeping total variable costs to a minimum so he can easily enter and leave fisheries. His perspective is short term (within-season), because he averages incomes and costs over many fisheries in the same fishing season, while a specialist fisher has a long-term (between years) view because he averages his good years with the bad ones for the same type of fishery (Smith and McKelvey 1986). Specialist fishers are therefore more likely to experience large interannual variation of fishing incomes (Kasperski and Holland 2013) but, if they are willing to accept this risk, they can obtain a higher longer term profit. Hilborn et al. (2001) said that “risk may be assessed and decreased, but not avoided” and fishers that are willing to accept a lower degree of risk also seem to be willing to accept a lower level of income.

To our best knowledge, this is the first study that empirically quantified the loss of economic performance of small-scale vessels caused by the diversification of *métiers* and thus in relation to the diversification of the fishing revenues. Therefore, while for some vessels increasing the diversity of the fishing *métiers* may limit the economic risk caused by the interannual variability of catches and prices and/or to reduce the operating costs, it can ultimately result in a less profitable activity than more specialised vessels. This finding highlights the importance of undertaking an in-depth analysis of the potential economic losses that policies promoting the diversification of the fishing *métiers* might cause at vessel level. In fact management measures encouraging fishers to diversify their fishing *métiers* by choosing among a diverse portfolio of harvestable resources may be strategic to reduce the pressure on overexploited stocks (Hilborn et al. 2001) but at the same time, may reduce the economic performance of single vessels. Managers might not be aware of the negative impact that diversification could cause to single vessels if the target management unit is the fleet as a whole.

The diversification of the fishing *métiers* used may result in very different (if not opposite) effects on yields and profit depending on the fishing unit considered (fleet vs vessel). Burgess (2014) stressed that in a multispecies fleet, as a whole, diversifying *métiers* can lead to increase yields, reduce threats to weak stocks and ultimately create opportunities for larger profits. On the other hand, the present study shows that at the scale of the individual vessels, the diversification of the fishing *métiers* used can result in a reduction of income and profit. As the increase of *métiers* diversity may reduce the profit of individual fishers, but may increase fishery-wide yields and profits (Burgess 2014), decision-makers should try to achieve an optimal trade-off where a balanced exploitation of multiple species induced by the use of multiple *métiers* can be reached while minimising the individual losses. The achievement of this optimal trade-off would enable fisheries managers to better implement EBFM and maintain long-term socioeconomic benefits without compromising the ecosystem.

Acknowledgement

Special thanks to the fishers involved for the valuable information they provided. We are grateful to the following Welsh fishing associations for promoting the project and for involving the fishers: Welsh Fishermen's Association, Cardigan Bay Fishermen's Association, Llyn Pot Fishermen's Association, Llyn Fishermen's Association, South and West Wales Fishing Communities, North Wales Fishermen's Co-operative, West Wales Shell Fisherman's Association and the Inshore Fisheries Group North. We finally thank two anonymous reviewers for the useful comments. Funding for this work was provided by the European Fisheries Fund.

References

Andersen, B. S., Ulrich, C., Eigaard, O. R., and Christensen, A. S. 2012. Short-term choice behaviour in a mixed fishery: investigating métier selection in the Danish gillnet fishery. ICES J. Mar. Sci. **69**(1): 131−143. doi:10.1093/icesjms/fsr181

Branch, T. A., Hilborn, R., Haynie, A. C., Fay, G., Flynn, L., Griffiths, J., Marshall, K. N., Randall, J. K., Scheuerell, J. M., Ward, E. J., and Young, M. 2006. Fleet dynamics and fishermen behaviour: lessons for fisheries managers. Can. J. Fish. Aquat. Sci. **63**(7): 1647–1668. doi:10.1139/f06-072

Burgess, M. G. 2014. Consequences of fleet diversification in managed and unmanaged fisheries. Can. J. Fish. Aquat. Sci. **72**(1): 54–70. doi:10.1139/cjfas-2014-0116

Cade, B. S., and Noon, B. R. 2003. A gentle introduction to quantile regression for ecologists. Front. Ecol. Environ. **1**(8): 412–420. doi:10.1890/1540-9295(2003)001[0412:AGITQR]2.0.CO;2

Cade, B. S., Terrell, J. W., and Schroeder, R. L. 1999. Estimating effects of limiting factors with regression quantiles. Ecology, **80**(1): 311–323. doi:10.1890/0012-9658(1999)080[0311:EEOLFW]2.0.CO;2

Cambiè, G., Kaiser, M. J., Marriott, A. L., Fox, J., Lambert, G., Hiddink, J. G., Overy, T., Bennet, S. A., Leng, M. J., and McCarthy, I. D. 2016. Stable isotope signatures reveal small-scale spatial separation in populations of sea bass. Mar. Ecol. Prog. Ser. **546**: 213–223. doi:10.3354/meps11636

Cambiè, G., Ouréns, R., Fernández-Vidal, D., Carabel, S., and Freire, J. 2012. Economic performance of coastal fisheries in Galicia (NW Spain): case study of the Cíes Islands. Aquat. Living Resour. **25**: 195–204. doi:10.1051/alr/2012010

Cochran, W.G. 1977. *Sampling Techniques.* 3rd edn. John Wiley and Sons, New York, NY. 428 pp.

Davie, S., Minto, C., Officer, R., and Lordan, C. 2015. Defining value per unit effort in mixed *métier* fisheries. Fish. Res. **165**: 1–10. doi:10.1016/j.fishres.2014.12.007

Davis, A., and Wagner, J. R. 2003. Who knows? On the importance of identifying ‘experts’ when researching local ecological knowledge. Hum. Ecol. **31**(3): 463–489. doi:10.1023/A:1025075923297

Deporte, N., Ulrich, C., Mahévas, S., Demanèche, S., and Bastardie, F. 2012. Regional métiers definition: a comparative investigation of statistical methods using a workflow applied to international otter trawl fisheries in the North Sea. ICES J. Mar. Sci. **69**(2): 331–342. doi:10.1093/icesjms/fsr197

DG MARE. 2015. Fleet Register on the Net. URL: http://ec.europa.eu/fisheries/fleet/index.cfm. Last accessed: 01/02/2015

Dray, S., and Dufour, A. B. 2007. The ade4 package: implementing the duality diagram for ecologists. J. Stat. Softw. **22**(4): 1–20.

Fulton, E. A., Smith, A. D. M., Smith, D. C., and van Putten, I. E. 2011. Human behaviour: the key source of uncertainty in fisheries management. Fish Fish. **12**(1): 2–17. doi:10.1111/j.1467-2979.2010.00371.x

Geraci, M. 2014. Linear quantile mixed models: The lqmm package for Laplace quantile regression. J. Stat. Softw. **57**(13): 1–29.

Geraci, M., and Bottai, M. 2014. Linear quantile mixed models. Stat. Comput. **24**(3): 461–479. doi:10.1007/s11222-013-9381-9

Gordon, H.S. 1954. The economic theory of a common-property resource: the fishery. J. Polit. Econ. **62**(2): 124–142. Available from http://www.jstor.org/stable/1825571 [accessed 1 December 2015]

Greenacre, M. 2006. From Simple to Multiple Correspondence Analysis. In M. Greenacre & J. Blasius (eds.), Multiple Correspondence Analysis and Related Methods, pp. 41–76. Chapman & Hall. London.

Greenacre, M., and Nenadić., O. 2010. ca: Simple, Multiple and Joint Correspondence Analysis. R package version 0.33. Available from http://CRAN.R-project.org/package=ca. [accessed 1 January 2015]

Guyader O., Berthou P., Koutsikopoulos C., Alban F., Demanèche S., Gaspar M. B., Eschbaum R., Fahy, E., Tully, O., Reynal, L., Curtil, O., Frangoudes, K., and Maynou, F. 2013. Small scale fisheries in Europe: a comparative analysis based on a selection of case studies. Fish. Res. **140**: 1–13. http://dx.doi.org/10.1016/j.fishres.2012.11.008

Haig, J., Pantin, J. R., Salomonsen, H., Murray, L. G., and Kaiser, M. J. 2015. Temporal and spatial variation in size at maturity of the common whelk (*Buccinum undatum*). ICES J. Mar. Sci. **72**(9): 2707–2719. doi:10.1093/icesjms/fsv128

Herrero, I., and Pascoe, S. 2003. Value versus volume in the catch of the Spanish south-Atlantic trawl fishery. J. Agric. Econ. **54**(2): 325–341. doi:10.1111/j.1477-9552.2003.tb00066.x

Hilborn, R. 1985. Fleet dynamics and individual variation: why some people catch more fish than others. Can. J. Fish. Aquat. Sci. **42**(1): 2–13. doi:10.1139/f85-001

Hilborn, R., and Kennedy, R. 1992. Spatial pattern in catch rates: a test of economic theory. Bull. Math. Biol. **54**(2): 263–273. doi:10.1007/BF02464833

Hilborn, R., Maguire, J.J., Parma, A.M. and Rosenberg, A.A. (2001) The precautionary approach and risk management: can they increase the probability of successes in fishery management? Can. J. Fish. Aquat. Sci. **58**(1): 99–107. doi:10.1139/f00-225

Holland, D. S. 2008. Are fishermen rational? A fishing expedition. Mar. Resour. Econ. **23**(3): 325–344. doi:10.1086/mre.23.3.42629621

Kaiser, M. S., Speckman, P. L., and Jones, J. R. 1994. Statistical models for limiting nutrient relations in inland waters. J. Am. Stat. Assoc. **89**: 410–423. doi:10.2307/2290841

Kasperski, S., and D. S. Holland. 2013. Income diversification and risk for fishermen. Proc. Natl. Acad. Sci. USA **110**(6): 2076-2081. doi:10.1073/pnas.1212278110

Koenker, R., and Bassett, G. 1978. Regression quantiles. Econometrica, **46**(1): 33–50. Available from: http://www.jstor.org/stable/1913643[accessed 1 February 2015]

Lawrence, S., and Anderson, J. 2014. 2012 Economic Survey of the UK fishing fleet. Seafish Report No SR669. ISBN No 978-1-906634-75-9.

Legendre, P., and Legendre, L. 1998. Numerical Ecology. Second English edition. Elsevier Science B.V., Amsterdam. 853 pp.

Marchal, P., Lallemand, P., and Stokes, K. 2009. The relative weight of traditions, economics, and catch plans in New Zealand fleet dynamics. Can. J. Fish. Aquat. Sci. **66**(2): 291–311. doi:10.1139/F08-193

Miller, P.R., McConkey, B.G., Clayton, G.W., Brandt, S.A., Staricka J.A., Johnston A.M., Lafond, G.P., Schatz, B.G., Baltensperger, D.D., and Neill, K.E. 2002. Pulse crop adaptation in the Northern Great Plains. Agron. J. **94**(2): 261–272. doi:10.2134/agronj2002.0261

Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fisher, J., Hutchings, J. A. 1999. Fisheries assessment: what can be learned from interviewing resources users. Can. J. Fish. Aquat. Sci. **56**(10): 1949–1963. doi:10.1139/f99-115

Pantin, J. R., Murray, L. G., Hinz, H., Le Vay, L., and Kaiser, M. J. 2015. The Inshore Fisheries of Wales: a study based on fishers' ecological knowledge. Fisheries & Conservation report No. 42, Bangor University. pp.60

Pelletier, D., and Ferraris, J. 2000. A multivariate approach for defining fishing tactics from commercial catch and effort data. Can. J. Fish. Aquat. Sci. **57**(1): 51−65. doi:10.1139/f99-176

Prellezo, R., Accadia, P., Andersen, J. L., Andersen, B. S., Buisman, E., Little, A., Nielsen, J. R., Poos, J. J., Powell, J., and Röckmanng, C. 2012. A review of EU bio-economic models for fisheries: The value of a diversity of models. Mar. Policy **36**(2): 423–431. doi:10.1016/j.marpol.2011.08.003

R Core Team. 2013. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from http://www.R-project.org/[accessed 1 June 2015]

Robinson, C., and Pascoe, S. 1997. Fisher Behaviour: Exploring the Validity of the Profit Maximising Assumption. Discussion paper 16. Centre for the Economics and Management of Aquatic Resources, Department of Economics University of Portsmouth, Portsmouth. 15 pp.

Rousseeuw, P.J. 1987. Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. J. Comput. Appl. Math. **20**: 53–65. doi:10.1016/0377-0427(87)90125-7

Salas, S., and Gaertner, D. 2004. The behavioural dynamics of fishers: management implications. Fish Fish. **5**(2): 153–167. doi:10.1111/j.1467-2979.2004.00146.x

Sethi, S.A. 2010. Risk management for fisheries. Fish Fish. **11**(4), 341–365. doi:10.1111/j.1467-2979.2010.00363.x

Smith, C.L, and McKelvey, R. 1986. Specialist and generalist: roles for coping with variability. North Am. J. Fish. Mana. **6**(1): 88–99. doi:10.1577/1548-8659(1986)6<88:SAG>2.0.CO;2

Squires. D., Vestergaard, N. 2013. Technical change and the commons. Rev. Econ. Stat. **95**(5):1769–1787. Available from http://EconPapers.repec.org/RePEc:tpr:restat:v:95:y:2013:i:5:p:1769-1787 [accessed 1 August 2016]

Tietze, U., Lash, R., Thomsen, B., and Rihan, D. 2005. Economic performance and fishing efficiency of marine capture fisheries. FAO Rome, Fish. Techn. pp. 482

Ulrich, C., and Andersen, B. S. 2004. Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. ICES J. Mar. Sci. **61**(3): 308–322. doi:10.1016/j.icesjms.2004.02.006

Van Iseghem, S., Quillérou, E., Brigaudeau, C., Macher, C., Guyader, O., and Daurès, F. 2011. Ensuring representative economic data: survey data-collection methods in France for implementing the Common Fisheries Policy. ICES J. Mar. Sci. **68**(8): 1792–1799. doi:10.1093/icesjms/fsr112

van Putten, I. E., Kulmala, S., Thébaud, O., Dowling, N., Hamon, K. G., Hutton, T., and Pascoe, S. 2011. Theories and behavioural drivers underlying fleet dynamics models. Fish Fish. **13**(2): 216–235. doi:10.1111/j.1467-2979.2011.00430.x

Ward, J. H. 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. **58**: 236–244. doi:10.1080/01621459.1963.10500845

Ward, J. M., Kirkley, J. E., Metzner, R., and Pascoe, S. 2004. Measuring and assessing capacity in fisheries. 1. Basic concepts and management options. FAO Fish. Techn. Pap. n◦ 433.

TABLES

Table 1. Technical and operational data per vessel for the three fleet segments of the Welsh fleet in 2012 (mean ± SD).

Technical features	**Scallop-dredge MS**	**Pots-and-nets MS**	**Pots-and-nets SS**
Age of the vessel (y)	20 (± 11.3)	27 (± 8.4)	16 (± 11.5)
GT (t)	47.9 (± 46.3)	21.6 (± 16.7)	3.9 (± 2.8)
Engine power (hp)	153.5 (± 10.5)	161.9 (± 136.5)	83.7 (± 68.2)
Length (m)	13.9 (± 5.2)	12.9 (± 3.3)	7.8 (± 1.6)
Crew (n)	4 (± 1.4)	3.8 (± 1.3)	1.5 (± 0.6)
Fishing days per year (n)	165.7 (± 81.3)	249 (± 39.3)	170.1 (± 59.2)

Table 2. Mean indicators of costs, profit and profitability per vessel per year for the three fleet segments of the Welsh fleet during 2012.

		Scallop dredge MS	**Pots and nets MS**	**Pots and nets SS**
Costs Indicators	Operating Costs (OC) (£)	64,520	132,334	16,028
	Maintenance Cost (MC) (£)	32,463	6,750	518
	Depreciation (D) (£)	38,054	12,991	8,457
	Administrative Costs (AC) (£)	12,719	12,396	2,908
	Opportunity Cost (OP) (£)	1,183	402	202
	Average Wage (AW) (£)	36,318	35,304	17,062
Profit Indicators	Vessel Physical Productivity (VPP) (t)	308.5	307.2	28.1
	Capacity Physical Productivity (CPP) (t)	6.3	10.4	7.6
	Vessel Productivity (VP) (£)	299,094	319,681	61,584
Profitability Indicators	Total Capital (TC) (£)	372,500	126,560	63,552
	Net Profit (NP) (£)	54,908	25,446	7,538
	Rate of Return on Investment (ROI) (%)	6.9	23.6	6.6

Table 3. Catch profiles of the 16 fishing *métiers* used by the studied fleet. Fishing gear is shaded grey and the corresponding *métiers* white. For each *métier*, target and secondary species are indicated as % catch weight. (Note that each fisher can use multiple *métiers* and therefore, the sum of the number of interviews of the *métiers* can be higher than the numbers of interviews of the corresponding gear). The 'abbreviations' for the *métiers* are defined here and have no further explanation.

Gear and *métiers*	No interviews	Target species	Secondary species
Lobster pot (FPOl)	**29**		
FPOl_1	12	Lobster (90.8%)	Brown crab (8.1%), Velvet crab (0.9%), Spider crab (0.2%)
FPOl_2	6	Spider crab (56.3%)	Brown crab (26.4%), Lobster (13.9%), Velvet crab (3.4%)
FPOl_3	23	Brown crab (59%)	Lobster (37.6%), Velvet crab (2.1%), Spider crab (1.3%)
Prawn pot (FPOp)	**10**		
FPOp_1	10	Prawn (100%)	
Whelk pot (FPOw)	**10**		
FPOw_1	10	Whelk (100%)	
Spider crab pot (SP)	**1**		
FPOsp_1	1	Spider crab (100%)	
Gill net (GNS)	**10**		
GNS_1	8	Sea bass (98.4%)	Cod (1.6%)
GNS_2	3	Grey mullet (62.6%)	Sea bass (20.7%), Cod (9%), Rays (5.2%)
Tangle net (TaN)	**7**		
TaN_1	5	Spider crab (100%)	
TaN_2	2	Crayfish (56%)	Flatfish (44%)
Trammel net (TrN)	**1**		
TrN_1	1	Rays (56%)	Dogfish (24.1%), Sole (16.8%), Cod (3.1%)
Rod and line (LHM)	**8**		
LHM_1	4	Mackerel (92.9%)	Sea bass (7.1%)
LHM_2	6	Sea bass (83.9%)	Mackerel (11.6%), Rays (4.5%)
Longline (LLS)	**3**		
LLS_1	3	Sea bass (100%)	
King scallop dredge (DRBk)	**6**		
DRBk_1	6	King scallop (100%)	
Otter trawl (OTB)	**1**		
OTB_1	1	Rays (51.8%)	Sole (22.9%), Plaice (22.1%), Cod (3.2%)

FIGURES

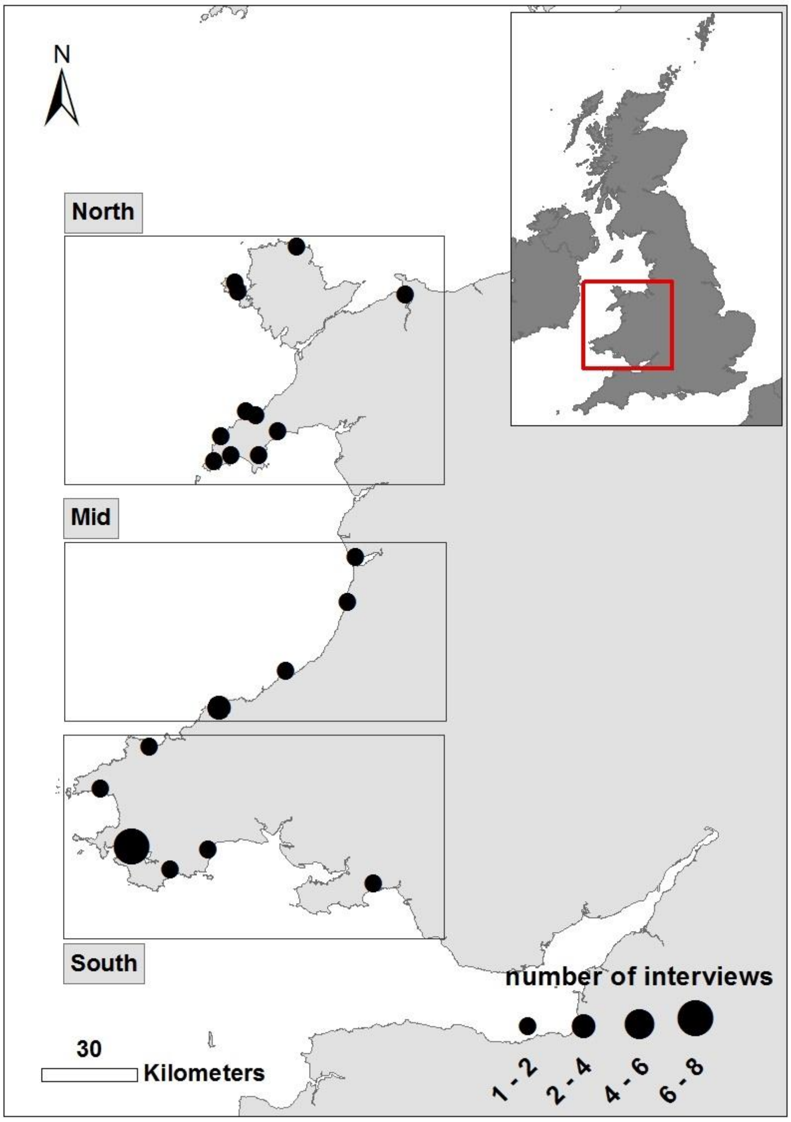

Figure 1. Study area showing the base ports of the vessel owners interviewed (Base map source: ESRI, 2015).

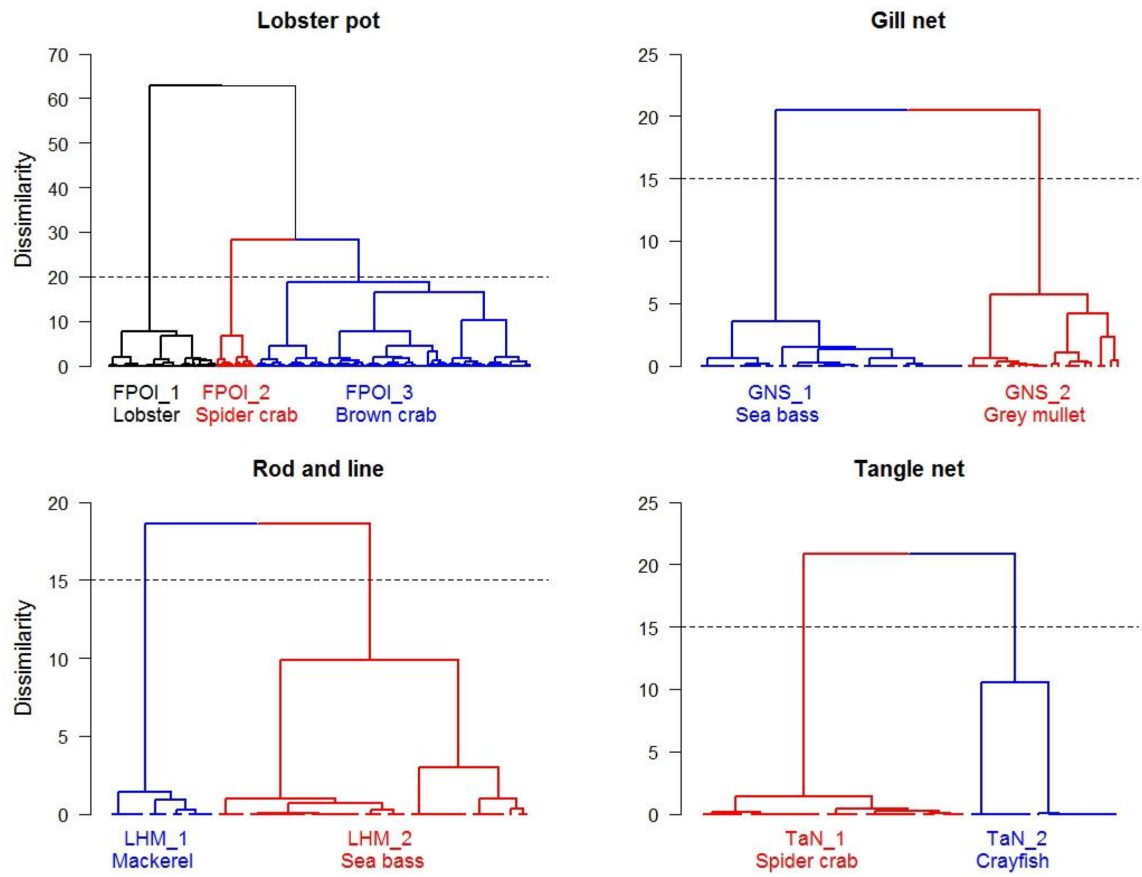

Figure 2. Dendrograms from hierarchical clustering using catch data. For each fishing gear, the dashed lines, which represent the cut-off point identified by the silhouette coefficient, determine the number of clusters. Each cluster identified a specific *métier*, indicated with acronyms and the names of the main target species.

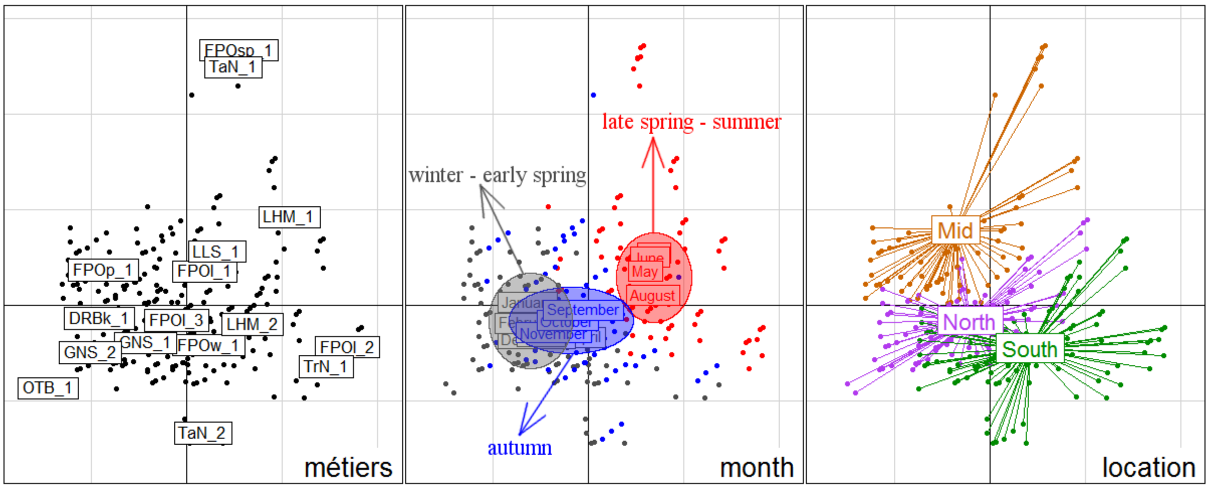

Figure 3. Multiple correspondence analysis showing the relationship between *métiers*, months and capture location. Each point represents a monthly fishing operation conducted by fishers from the three small-scale and medium-scale segments identified during 2012.

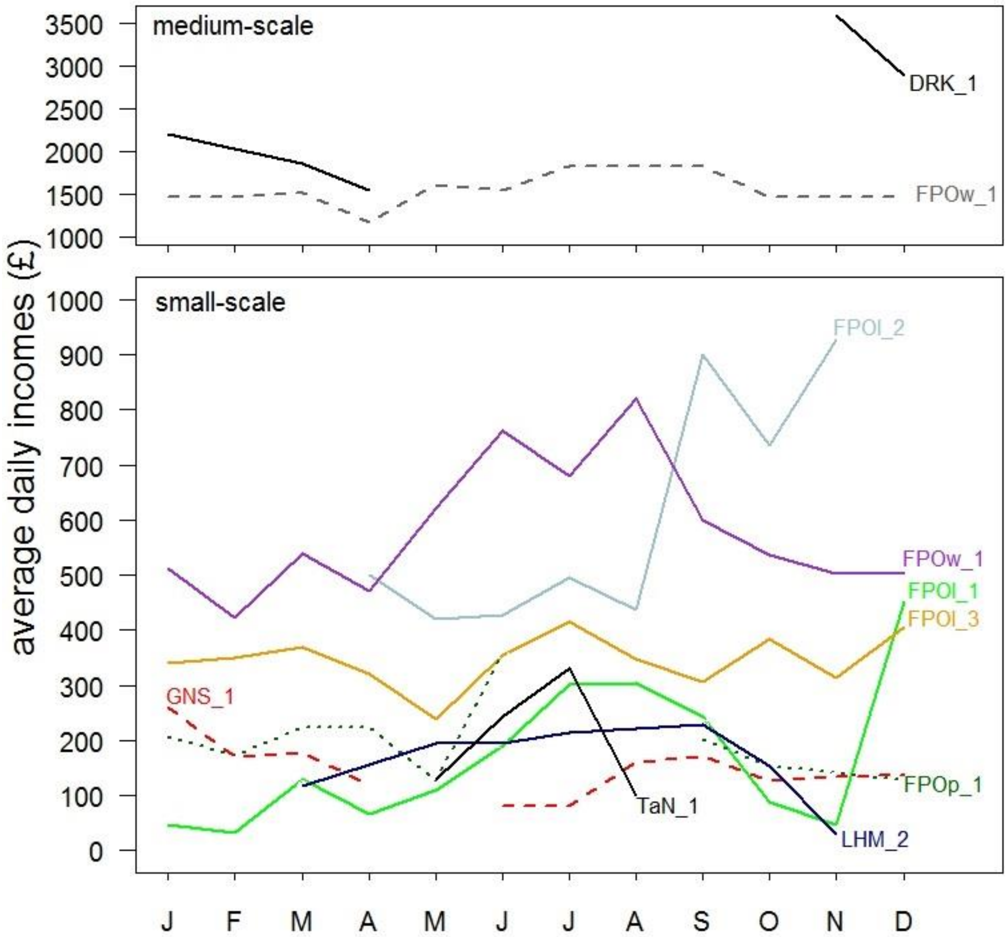

Figure 4. Average daily incomes by month associated to the main fishing *métiers* used by the small-scale (bottom) and medium-scale (top) segments during 2012 (Abbreviations given in Table 3).

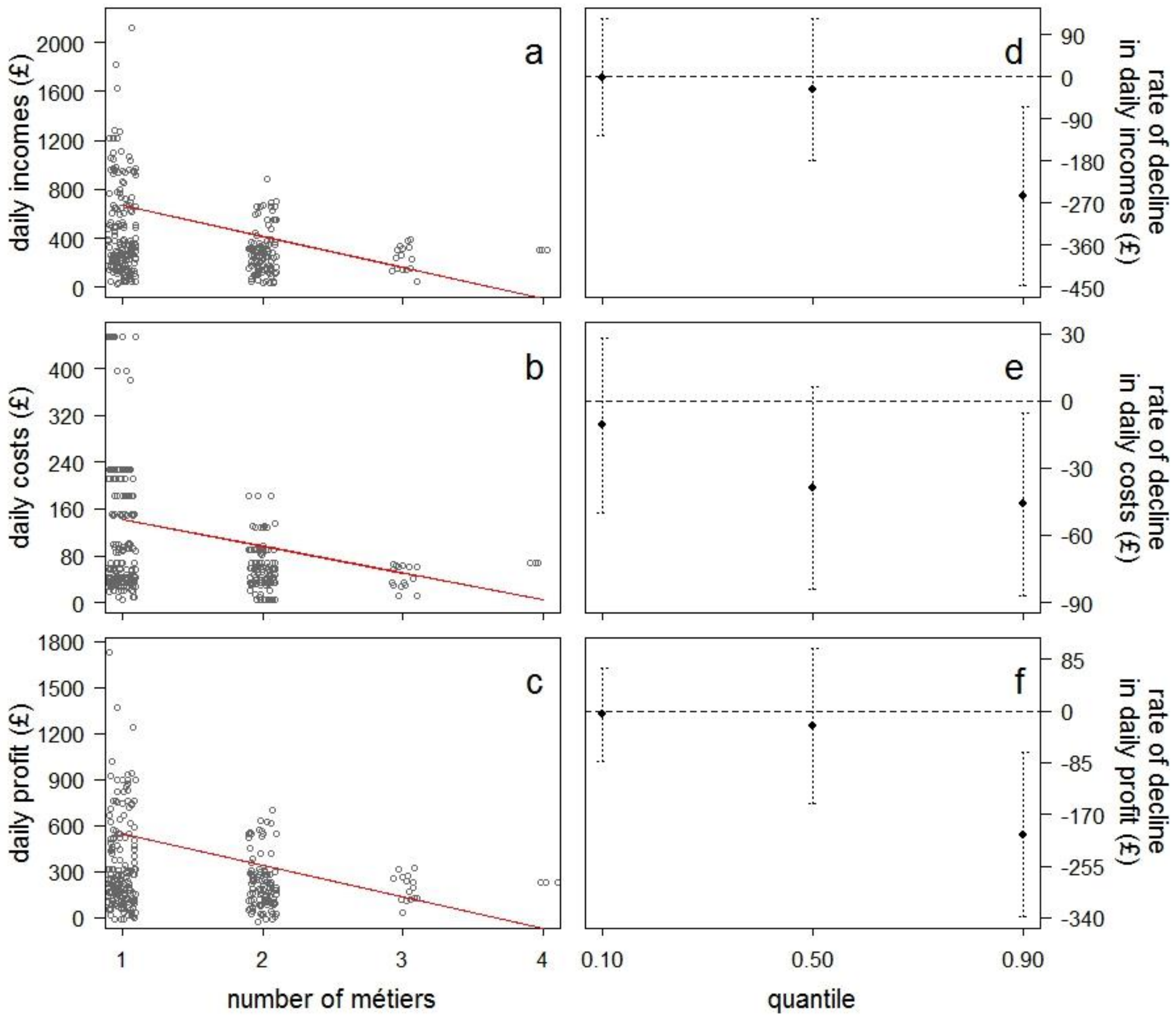

Figure 5. (Left) Relationship between the number of *métiers* per vessel used on a monthly basis and the relative daily incomes (a) operating costs (b) and operating profit (c) for small-scale vessels. Red lines represent the quantile regression fit of the 90th quantile as estimated from the LQMM model. (Right) Magnitude of the decline (slope) of daily incomes (d), daily operating costs (e) and daily operating profit (f) and their 95% confidence intervals (error bars) for the increase of the number of the *métiers* used on a monthly basis with increasing quantile level (0.1, 0.5 and 0.9). X values in a, b and c are jittered for presentation purposes only to show overlapping values.